FLUID POWER - HYDRAULICS

Background:

Fluid power is the technology that deals with the generation, control, and transmission of power using pressurized fluids. A fluid power system accomplishes two main objectives. First it provides a substantial force to move actuators in locations away from the power source, where the two are connected by pipes, tubes, or hoses. Second, fluid power systems accomplish highly accurate and precise movement of the actuator with relative ease. Fluid Power includes hydraulics, which involves liquids, such as oil or water, and pneumatics, which involves gases, generally air. Liquids provide a very rigid medium for transmitting power and thus can provide huge forces to move loads with utmost accuracy and precision. Pneumatic systems exhibit spongy characteristics due to the compressibility of the air, however, pneumatic systems are less expensive to build and operate and provisions can be made to the actuators to account for the less accurate control. The focus of this laboratory will be the application of hydraulic power, however, many of the same principles can be applied to pneumatic systems.

Pascal's law reveals the underlying principle of how fluid transmits power. It states that pressure applied to a confined fluid is transmitted undiminished in all directions and acts at right angles to the inside walls of the container. The law can be extended to include the transmission and multiplication of force. The example of figure 1, a hydraulic press, shows how a small force exerted on a small area can create a proportionally larger force on a larger area. An input force of 10 lb is applied to a 1 in^2 piston. This develops a 10 psi pressure throughout the container. When the 10 psi pressure acts on a 10 in^2 piston, a 100 lb output force is produced. Thus, the only limit to the force a machine can exert is the area to which the pressure is applied and the material strength of the container.

The hydraulic press of figure 1 is only one basic application of fluid power. Hydraulics are used in numerous applications including the brakes, automatic transmission and power steering in automobiles. Naval systems use hydraulic power extensively. Aboard ship, hydraulic power is used to operate such equipment as anchor windlasses, cranes, steering gear, and power drives for launchers. Aircraft use hydraulic systems for the actuation of landing gear, doors and hatches, as well as nosewheel steering and brakes. Even with the advent of "fly by wire" technology in modern airplanes, electronic signals are sent to hydraulic actuators.

Virtually all hydraulic circuits are essentially the same regardless of the application. There are six basic components required in a hydraulic circuit:

1. A tank (reservoir) to hold the liquid, which is usually hydraulic oil.
2. A pump to force the liquid through the system.
3. An electric motor or other power source to drive the pump.
4. Valves to control liquid direction, pressure, and flow rate.
5. An actuator to convert the energy of the liquid into mechanical force or torque to do useful work. Actuators can be either cylinders to provide linear motion or motors to provide rotary motion.
6. Piping which carries the liquid from one location to another.

In hydraulic systems, fluid from the reservoir enters the pump at below atmospheric pressure, called the suction pressure. As the fluid passes through the pump its energy increases, as evidenced by an increase in fluid pressure. The pressurized fluid is then directed towards the actuator through the hydraulic lines. Some of the energy is lost due to friction as the fluid flows through pipes, valves, and fittings. These frictional losses show up as heat and must be accounted for when designing a hydraulic system. At the output device (hydraulic actuator), the remaining energy is transferred to the load to perform useful work. This is essentially the cycle of energy transfer in a hydraulic system. Energy is added to the system by a pump and removed from the system via the actuator as it drives the load.

Since the source of energy for the system is the electric motor that drives the pump it is logical to question why hydraulics are necessary. Why not simply couple the mechanical equipment directly to the electric motor? The answer to this question highlights the reason for the widespread us of hydraulic power: a hydraulic system is much more versatile in its ability to transmit power. This versatility includes advantages of variable speed, reversibility, overload protection, high horsepower to weight ratio, and immunity to damage under stall conditions. In addition, through the use of control valves, a single power source connected to a hydraulic system can operate many actuators and perform multiple functions.

References:

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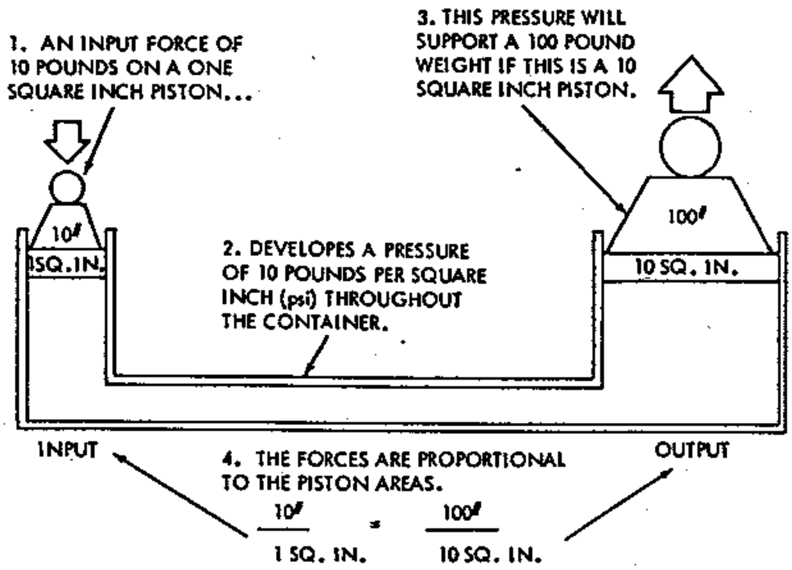

Figure 1. Hydraulic Jack

Apparatus:

The apparatus used in this laboratory is a self contained hydraulics work bench. The permanent components of the bench consist of a reservoir of hydraulic oil, an electric motor driving a constant displacement pump, and a pressure relief valve. Additional components available include pressure gages, valves (shut off, directional control, pressure relief, flow control, etc.) and linear actuators. A complete hydraulic circuit is made by locking the desired components into the board on the bench and connecting the components with hydraulic hoses. This is a fail safe piece of equipment since the permanent pressure relief valve connected to the pump will discharge the hydraulic fluid to the reservoir if there is an overload or blocked path in the circuit. An emergency stop button on the control panel is also available in case of unexpected problems.

Objective:

The object of this lab is to investigate the principles of hydraulic power by performing the simple task of raising and lowering a weight. The students will gain familiarity with the basic components used in a hydraulic circuit and learn how to vary the performance of the actuator with control valves.

Procedures:

Exercise 1

The first exercise will demonstrate how to raise and lower a weight using a linear (piston in cylinder) hydraulic actuator. The student should assemble the hydraulic circuit diagramed on figure 2, consisting of:

(1) an electric motor
(2) a constant displacement pump (with pressure relief valve)
components (1) and (2), are contained within the basic unit
(3) a pressure relief valve
(4) a pressure gage
(5) a shut off valve
(6) a lever actuated, spring offset, 4/2 directional control valve
(7) a double acting cylinder

Procedure

(1) Close shut off valve and record pressure. Open shut off valve.
(2) actuate and release lever on 4/2 directional control valve. Note position of actuator and system pressure with regards to the position of the lever.
(3) Hang weight from end of actuator, repeat (1) and (2).

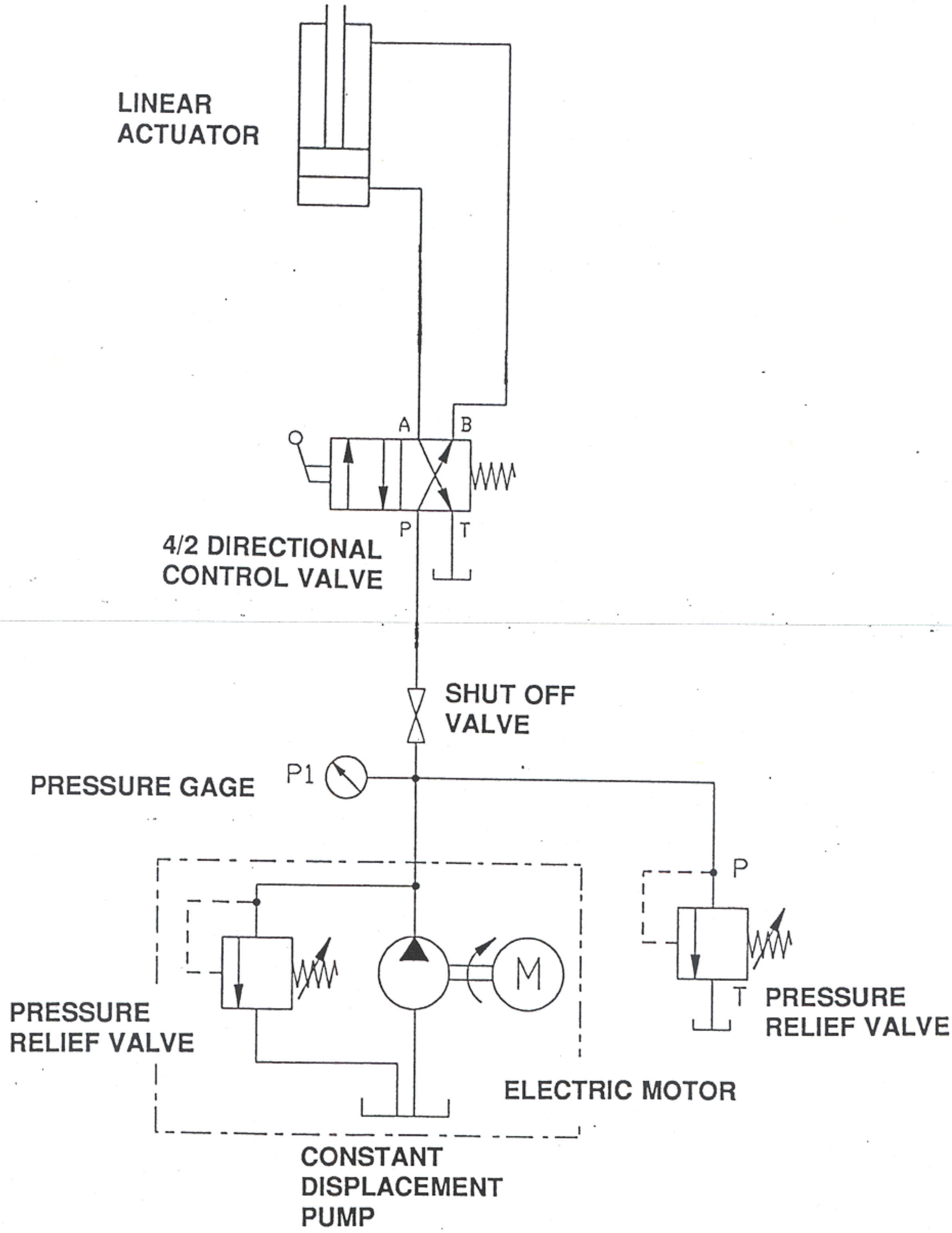

Figure 2. Circuit for Exercise 1

Exercise 2

The second exercise demonstrates the use of flow control valves to vary actuator speed. A flow control valve, figure 3, is a restriction used to reduce the flow to an actuator. When a flow control is placed in a circuit, the difference in pressure from one side to the other (pressure drop) determines the flow rate to the actuator.

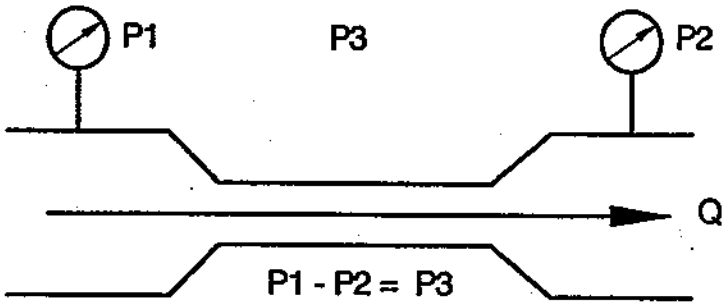

Figure 3. Flow Control Valve

Construct the circuit show on figure 4. Additional components are:

(8) a flow control valve
(9) a second pressure gauge

Procedure

(1) open the flow control valve completely. Note pressures before and after the valve.
(2) without the weight, record the time it takes the actuator to go from the fully retracted to fully extendedposition.
(3) repeat (1) and (2) with the flow control valve partially closed. Obtain several readings.
(4) repeat (1) - (3) with the weight hanging from the end of the actuator.

Results

Without Weight		With Weight	
Valve Position	Time (s)	Valve Position	Time (s)

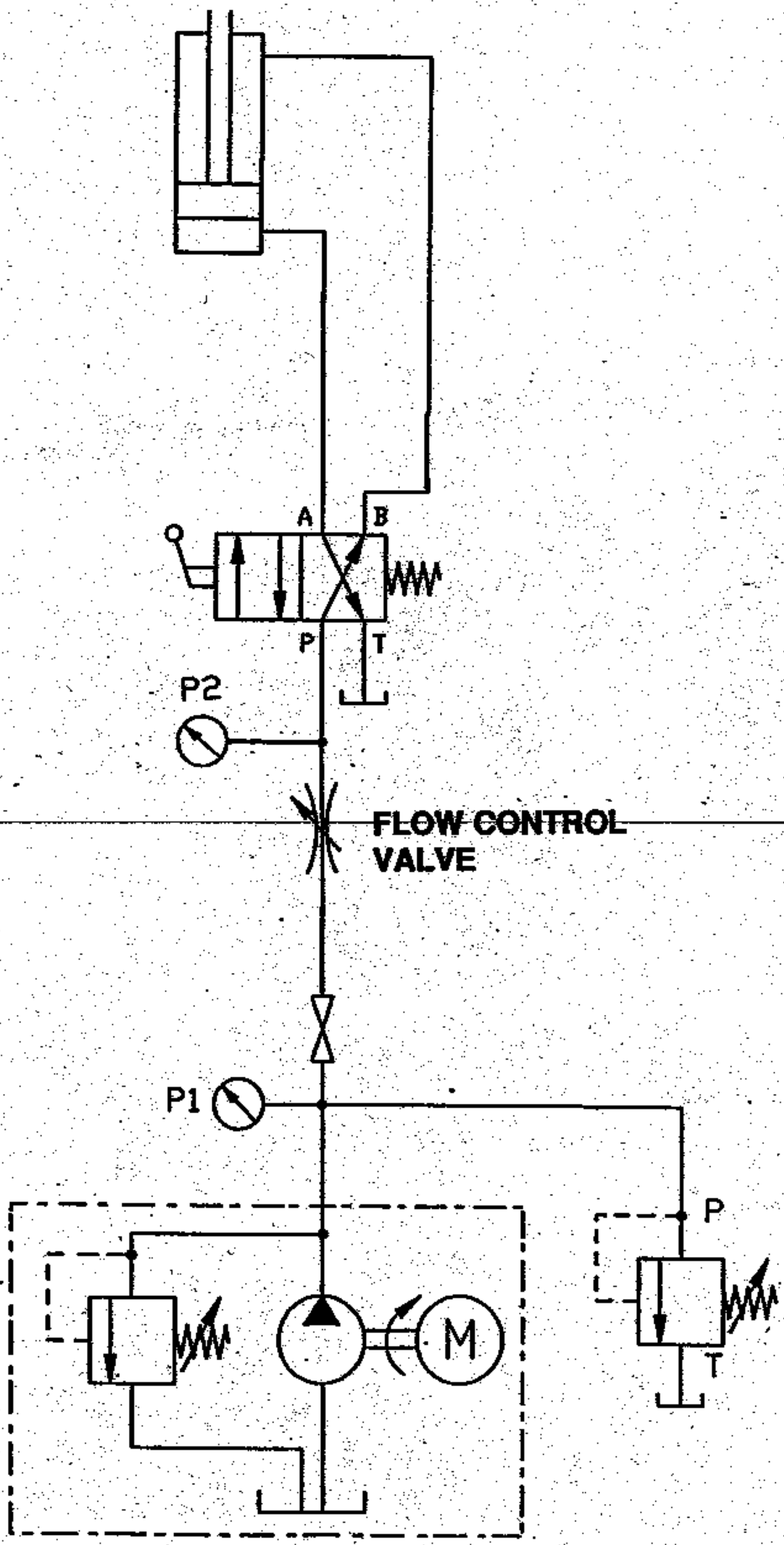

Figure 4. Circuit for Exercise 2

Exercise 3

The third exercise demonstrates the use of check valves in a hydraulic circuit. A check valve permits flow in one direction only. Figure 5 illustrates a simple check valve. Fluid can flow from A to B since the fluid force unseats the valve. However, if the direction of flow is changed, the flow from B will be blocked by the spring loaded check assembly. A pilot operated check valve performs the same function as a check valve when it is unactuated. As demonstrated on figure 6, fluid will flow from A to B, however is block from B to A. When pilot pressure is applied at X, pressure is exerted on a piston (1) which in turn unseats the check valve. Fluid can now flow from B to A.

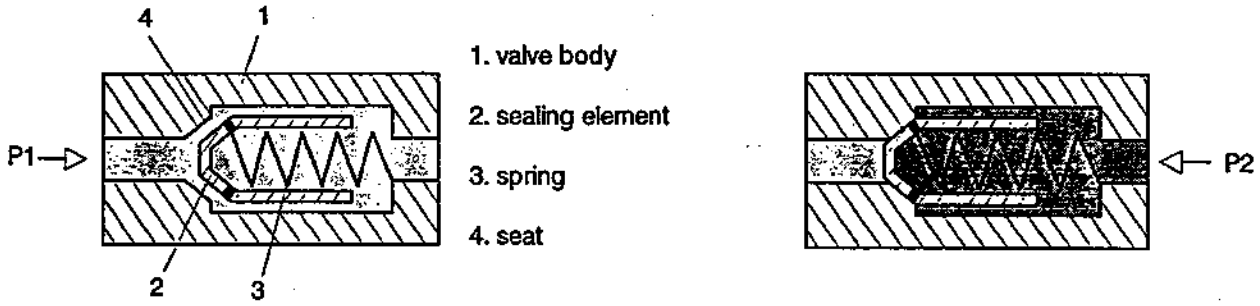

Figure 5. Check Valve

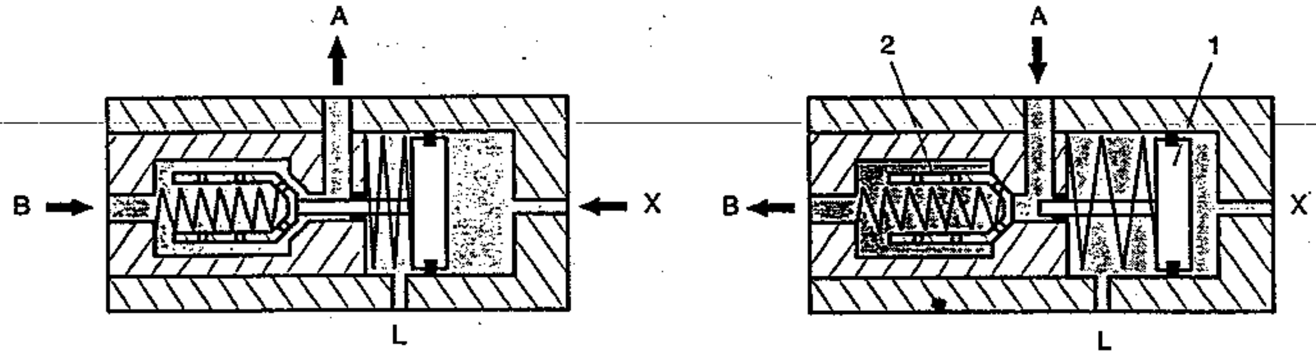

Figure 6. Pilot Operated Check Valve

The circuit shown in figure 7 uses a pilot operated check valve to hold the actuator in a desired position. Recall that the circuit in exercise 1 did not allow the actuator to be stopped except in the fully retracted position.

Remove the flow control valve and pressure gage used in exercise 2 and construct the hydraulic circuit on figure 7. Additional components necessary are:

(10) a piloted check valve
(11) a lever actuated, spring offset, normally closed, 3/2 directional control valve

Procedure

(1) By actuating and releasing the levers on the 2 directional control valves, find the lever positions necessary to hold and lock the actuator while lowering and raising the weight.

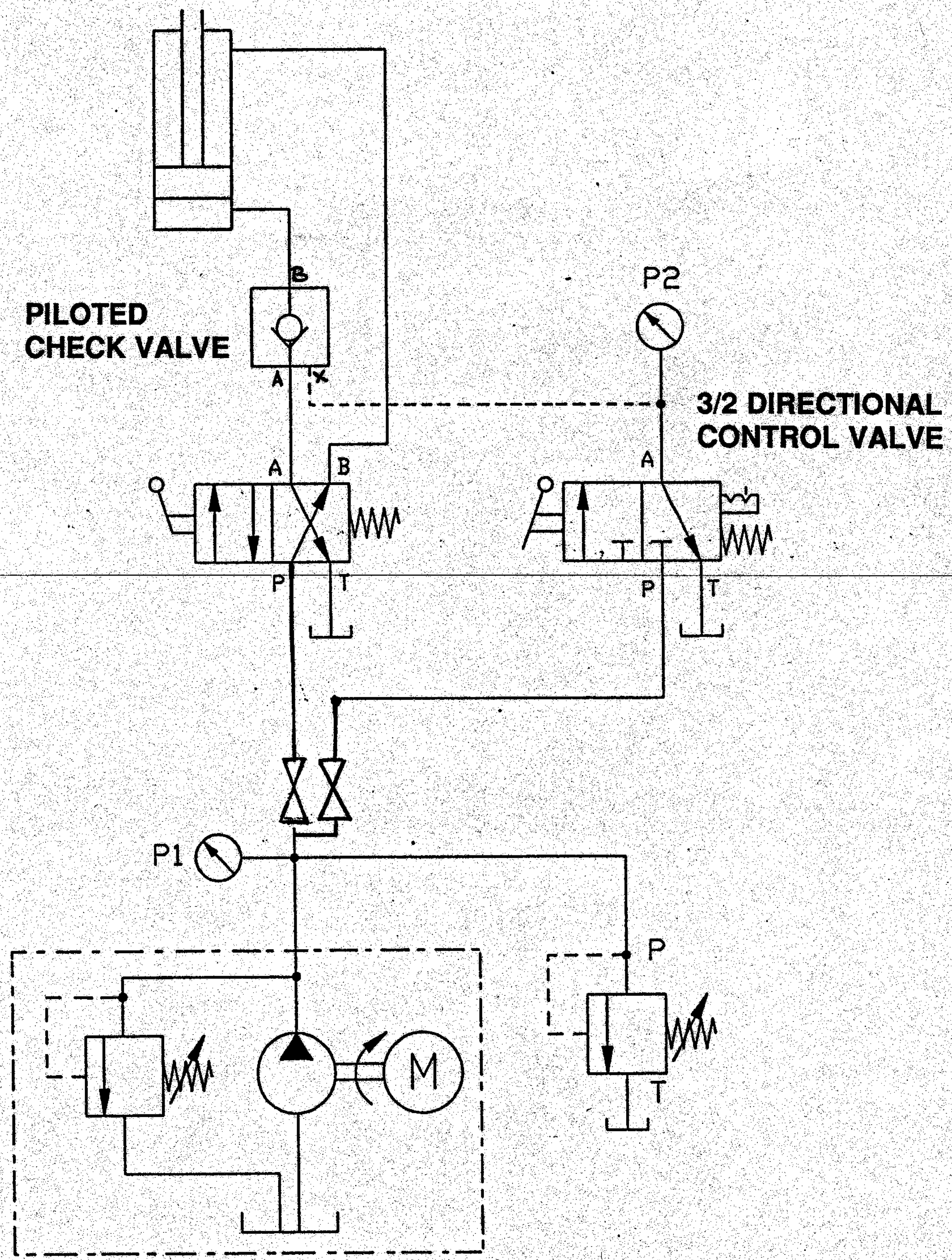

Figure 7. Circuit for Exercise 3

Questions - Exercise 1

(1) With the shut off valve closed, how does the hydraulics fluid coming from the pump return to the reservoir?

(2) Does the weight raise or lower when the lever on the 4/2 valve is actuated? Why does the weight go in the opposite direction when the lever is released?

(3) Is the system pressure the same when raising and lowering the weight? How does it change?

(4) Is it possible to stop the actuator in a partially deployed position?

(5) Describe an application that would use this type of hydraulic circuit.

Questions - Exercise 2

(1) Does the speed of the actuator increase of decrease with increased pressure drop across the flow control valve?

(2) What happens to the speed of the actuator when the weight is added? Why?

(3) Describe an application that would use this type of control.

Question - Exercise 3

(1) Describe an application that would require this type of control.